# High-Resolution Modeling of Canadian Rockies Snow Pack as part of the Canadian Land Data Assimilation System (CaLDAS)

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## Canadian Land Data Assimilation System (CaLDAS)

• Over the last several decades, it has become increasingly clear that the evolution of the atmospheric boundary layer is significantly influenced by fluxes of heat, moisture and momentum from the land surface.

• Land-surface models and assimilation systems have been used for a few decades to provide surface conditions and fluxes for numerical weather prediction (NWP) systems.

• In an effort to better represent land surface processes in environmental prediction systems (weather, hydrology, land surface), a new version of the Canadian Land Data Assimilation System (CaLDAS) is currently being developed at Environment Canada.

## National Agri-Environmental Standards Initiative (NAESI)

• Collaborative project between Environment Canada and Agriculture Canada which had as a goal to produce water-balance indicators using a coupled hydrometeorological modeling system for the South Saskatchewan River Basin (SSRB) located in western Canada.

• The Interaction Sol-Biosphère-Atmosphère (ISBA) land-surface model was integrated in an external mode over the SSRB at two horizontal resolutions : a 15-km grid similar in size to that of the regional NWP system operational at the Canadian Meteorological Centre , and on an experimental 1-km grid.

• Owing to the impact of snow accumulation and subsequent melt upon the streamflow regime within the SSRB, we present an evaluation of the simulated Rocky Mountain snow pack, including issues related to both the snow water equivalent (SWE) and snow cover extent and duration.

## Description : Land Surface Modeling Components

•**Land-Surface Model** : Interaction Sol-Biosphère-Atmosphère (ISBA) (Noilhan and Planton 1989; Bélair et al. 2003ab).

•**Atmospheric Forcing** : In the external mode the atmospheric forcing data comes from 6-18 hr Regional Global Environmental Multiscale (GEM) model forecasts (Mailhot et al. 2006).

– Forcing variables :
– shortwave and longwave radiation incident at the surface
–air temperature and specific humidity (z ≈ 50 m)
–zonal and meridional wind components (z ≈ 50 m)
–surface pressure

•**Precipitation Forcing** :
– Regional GEM model forecasts
– Canadian Precipitation Analysis (CaPA; Mahfouf et al. 2007)

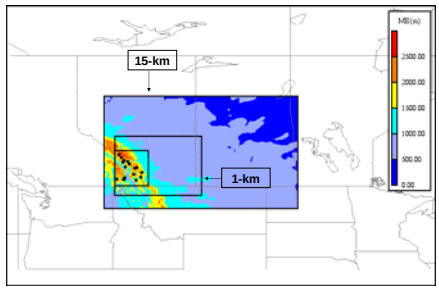
•**Geophysical Fields** :
– **Orography** : Shuttle Radar Topography Mission Digital Elevation Model (SRTM-DEM) with a 90-m pixel size over Canada and the Canadian Digital Elevation Data (CDED, 1:50,000)
– **Soil texture** : Food and Agriculture Organization (FAO) database
– **Vegetation characteristics** : a global 1-km USGS database

•**Methodology** : The simulations are based on a continuous cycling of 24-hr integrations of the ISBA land surface model with a time step of 30 min.

## Summary of Sensitivity Experiments

| Experiment Name | Land Surface Scheme | Grid-Size (km) | Time Period | Adaptation of Meteorological Forcing | Precipitation Forcing |
|---|---|---|---|---|---|
| CaPA-15 | ISBA | 15 | 20/5/2004 – 31/10/2007 | No | CaPA |
| GEM-15 | ISBA | 15 | 20/5/2004 – 31/10/2007 | No | GEM |
| CaPA-1 | ISBA | 1 | 20/5/2004 – 31/10/2007 | Yes | CaPA |
| GEM-1 | ISBA | 1 | 20/5/2004 – 31/10/2007 | Yes | GEM |

## Model Computational Domains



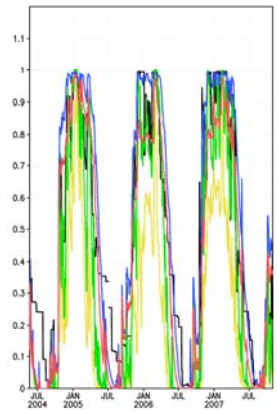

## Verification Data Sets

• **Interactive Multisensor Snow and Ice Mapping System (IMS) from NOAA** : The IMS analysis incorporates data from various satellite platforms along with derived mapped products and surface observations (Ramsay 1998). The data are available on a polar stereographic projection at both 24 km and 4 km resolutions. Classify data points as either land, sea, sea ice or snow.

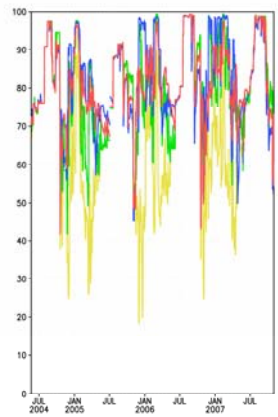
• **Manual Snow Surveys** : Within the Canadian Rockies the British Columbia Ministry of Environment maintains a series of manual snow survey site which are sampled on a monthly basis throughout the winter-spring season. For each snow course site, the recorded snow depth, snow water equivalent and snow density values represent averages from a sample of sites measured. (http://www.env.gov.bc.ca/rfc/).

## Snow Coverage Extent and Duration

Snow Cover Fraction

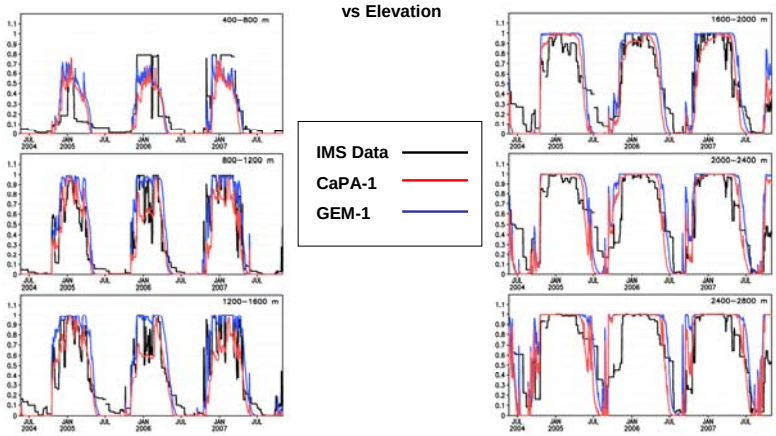



Percentage of Matching Pixels



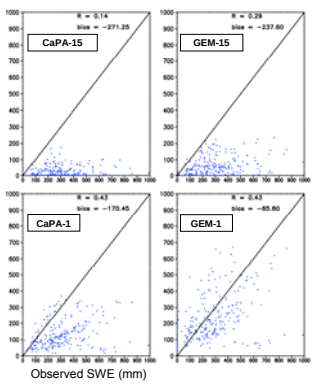

Snow Cover Fraction

Snow Cover Fraction vs Elevation




## Snow Water Equivalent (SWE)

Simulated SWE (mm)




Observed SWE (mm)

## Summary and Conclusions

• Increasing the horizontal resolution of the ISBA land surface model significantly improved the representation of the snow pack in the Rocky Mountains.

• Snow pack simulations were found to be sensitive to the precipitation forcing, with precipitation from CaPA leading to a weaker contribution to streamflow compared with precipitation directly retrieved from Environment Canada's GEM model.

•Tendency for the high-resolution simulations to melt the mountain snow pack too quickly during the spring melt season.

References :

Bélair, S., L.-P. Crevier, J. Mailhot, B. Bilodeau and Y. Delage, 2003a : Operational implementation of the ISBA land surface scheme in the Canadian regional weather forecast model. Part I: Warm season results. Journal of Hydrometeorology, 4, 352-370.

Bélair, S., R. Brown, J. Mailhot, B. Bilodeau and L.-P. Crevier, 2003b: Operational implementation of the ISBA land surface scheme in the Canadian regional weather forecast model. Part II: Cold season results. Journal of Hydrometeorology, 4, 371-386.

Mahfouf, J.-F., B. Brasnett and S. Gagnon, 2007: A Canadian Precipitation Analysis (CaPA) Project: Description and Preliminary Results. Atmosphere-Ocean, 45(1), 1-17.

Mailhot, J. and coauthors, 2006: The 15-km version of the Canadian Regional Forecast System. Atmosphere-Ocean, 44(2), 133-149.

Noilhan, J., and S. Planton, 1989: A simple parameterization of land surface processes for meteorological models. Monthly Weather Review, 117, 536-549.

Ramsay, B. H., 1998 : The Interactive Multisensor Snow and Ice Mapping System, Hydrol. Proc., 12, 1537-1546.